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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Pesticide exposure from fresh tomatoes and its relationship with pesticide application practices in Meru district

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Abstract: Tomato pesticides health risk was assessed in Meru district of Arusha region, one of the key tomato producers in Tanzania. Tomato samples and consumption information were collected from 50 farmers using Food and Drug Administration standards and twice administered twenty-four hour recall questionnaire respectively. Analysis for pesticide residues was done using Gas Chromatography Mass Spectrometry. Dietary pesticide exposure was estimated deterministically by combining pesticide residue levels and tomato consumption levels. Pesticide levels were detected for; permethrin (mean, 5.2899 mg/kg), chlorpyrifos (mean, 7.5281 mg/kg) and ridomil (mean, 2,854.279 mg/kg) in 18% of samples. Health Risk Indices, determined as ratio of estimated daily intake to acceptable daily exposure, for chlorpyrifos, permethrin and ridomil were greater than one. This implies that, lifetime consumption of fresh tomatoes can pose health risk for chlorpyrifos, permethrin and ridomil. Awareness raising on good practices for pesticide application and food safety strengthening are recommended to protect public health against pesticides.

Subjects: Bioscience; Environment & Agriculture; Food Science & Technology

Keywords: farmers; health effects; pesticide; pesticide exposure; pesticide residues; tomato

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PUBLIC INTEREST STATEMENT

This paper has explored pesticide application practices during tomato production and its implication to pesticide residues and the associated risks of dietary pesticide exposure.

It has been found that pesticide residues found in tomatoes are higher than the recommended limits and might cause health risks to consumers. These findings will provide evidence for policy-makers to develop strategies of reducing risk to consumers and serve as a basis of training farmers on pesticide use as well as strengthen food safety system in Tanzania. In the long run, safe tomatoes will be consumed and the public will be protected from any fatal health risks associated with pesticides exposure.

This will consequently, promote health and nutrition well-being of tomato consumers in Tanzania and the nearby countries.

1. Introduction

Pesticides use in tomato production to reduce the food loss which result from occurrence of resistant pests and diseases is inevitable (Hossain et al., 2013; Ngowi, Mbise, Ijani, London, & Ajayi, 2007; Oliveira Pasiani, Torres, Roniery Silva, Diniz, & Caldas, 2012). Just like in other areas, farmers in Tanzania are known to applying different types of fungicides, insecticides and herbicides to secure tomatoes from pests and diseases without considering the effects of the pesticides on environment or human health (Mdegela, Mosha, Ngowi, & Nonga, 2013; Ngowi et al., 2007). Misuse of these pesticides in vegetable production led to chemical polluting the soil and irrigation water as it was reported in 2010 in Ngarenanyuki and Uwiro estate of Meru district. (Kihampa, Mato, & Mohamed, 2010a, 2010b). Also, improper pesticide application on crops may contribute to accumulation of residues in food materials. Consumption of pesticide contaminated food may result in serious exposures of the chemicals and consequently health problems (Al-Waili, Salom, Al-Ghamdi, & Ansari, 2012; Dewhurst & Marrs, 2009; Kihampa et al., 2010a; Ntow, Gijzen, Kelderman, & Drechsel, 2006). Dietary exposure of pesticides is especially high when food commodities are consumed fresh (Solecki et al., 2005).

In Tanzania, despite the established evidence of intensive use of pesticide in tomato farming, and presence of pesticide residues in irrigation water, there is limited information on pesticide residues in tomatoes as well as possible dietary exposure of pesticide from fresh tomatoes. In this regard, this study investigated pesticide application practices which are associated with accumulation of residues and exposure in fresh tomatoes in Tanzania. This information will be useful in improving food safety system in Tanzania and subsequently contribute to protecting and promoting public health.

2. Material and methods

2.1. Study site

The study was conducted in the Meru district of Arusha region. Within Arusha region, Meru district has the highest number of tomatoes growing households and the highest percentage of tomatoes production (3,050 or 66 percent of tomatoes) (Ministry of Agriculture Food Security & Cooperatives, 2012). Arusha has 1.351 (5.2%) hectares of area planted with tomatoes and yield 14 tons of tomatoes per hector. Within the region, the total production of fruits and vegetables is 30,549 tons, of which tomato accounts for 61.8% (18,866 tons) (Ministry of Agriculture Food Security & Cooperatives, 2012).

2.2. Recruitment of farmers

A total of 50 adult tomato farmers were recruited for this study; 25 from Nduruma and 25 from Ngarenanyuki ward. The wards were purposively selected for the study as they are a key source of tomatoes in Meru district. The simple random sampling technique was employed for selection of individual farmer based on their involvement in tomato farming, possession of not less than one acre of tomato farm and involvement in tomato business.

2.3. Data and sample collection

A standardized questionnaire with structured and semi structured questions was used to get the information shown in Table 1. Socio—demographic and pesticide handling practices information were collected, on farm, from all the 50 farmers, using face to face interview. Fifty (50) samples of tomatoes, each consisting one kg of approximately eight (8) medium sized tomatoes according to Food and Drug Administration (FDA), were collected for analysis (Client guidelines, Field Sampling for Pesticide Analysis. Retrieved from http://www.primuslabs.com/services/CG-FieldSamplingforPesticideAnalysis.pdf). Sample packaging and storage was done according to Food Safety and Standards Authority of India (FSSAI, 2012) and FDA. Each sample was kept in a separate sterile polyethene bag, sealed, labelled with unique sample identity, placed in ice chest box, transported to Tropical Pesticides Research Institute (TPRI) laboratory and stored at 4°C until analysis.

2.4. Pesticide determination in tomato

Pesticide residues determination was done using QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method of AOAC (Association of Official Agricultural Chemists Official) 2,007.01 as

Table 1. Type and details of information collected during the survey

Type	Details
Socio-demographic	Gender, age, occupation, education
Tomato production	Farm size, duration of farming, working hours
Pesticide application practices	Trend, types, sources, use frequency, application methods, handling, disposal of containers, reasons and ways for application
Pesticide health effects	Awareness of pesticide effects, types of effects, affected group of people,
Farmers' knowledge and skills	Training on pesticides, assistance from extension officer, ability to use the acquired skills

described by Lehotay (2007). Pesticides were extracted with 15 ml ethyl acetate solvent from a portion of 15 g of tomato which was weighed into a 50 ml tube and 100 μL of Heptachlor added as internal standard. 6 gm of Magnesium Sulphate and 1.5 g of sodium acetate was added into the mix. The pesticides were extracted by shaking the mix and then centrifuging it for five minutes. For clean-up, 3 ml of supernatant was kept in 15 ml tube where 300 mg of Magnesium Sulphate and 150 mg of Primary Secondary Amine were added to remove polar interferences, including sugars and organic acids. The mixture was shaken using a vortex then centrifuged and the supernatant was then analyzed using gas chromatography mass spectrometry (GC–MS).

2.5. GC-MS analysis condition

GC-MS analyses were performed on an Agilent 7890A GC system coupled to a 7000B triple quadrupole mass spectrometer. Both systems were equipped with a 7693 auto injector. The inlet temperature was 250°C, the total flow was set at 50 ml/min, and a split valve was opened one minute after pulsed split less injection (25 psi). The injection volume was one μL. A fused silica capillary column with DB (30 m × 0.25 mm i.d. × 0.25 μm) film thickness was used. At the beginning of injection, the oven temperature was set at 60°C for one minute, ramped to 300°C at 20°C/min and then held for three minutes. The helium carrier gas flow rate was constant at 1.20 ml/min, and the transfer line temperature was set at 280°C. The GC–MS was operated in a scan or SIM mode and the product ion scan mode. The source temperature was 230°C.

2.6. Estimation of tomato consumption

A twenty-four hour dietary recall questionnaire was administered twice within a week to assess consumption of fresh tomatoes. Farmers were asked to state the meals taken in the previous day and the number of fresh tomatoes consumed as compared to the unit weight of medium sized tomato. Prior to administration of the 24 h dietary recall, each farmer received one medium sized tomato in order to assist in reporting portion sizes of fresh tomato intake. A unit weight of the medium sized tomato of 125 g was used to get the total weight of the consumed tomatoes per individual farmer as described by International Programme on Chemical Safety IPCS (2009). The information on consumption of fresh tomato for two days was used to get the average consumption for each individual farmer.

2.7. Estimation of pesticide exposure

Probable daily pesticide exposure or Estimated Daily Intake for each pesticide and farmer was calculated using the following formula:

$$\mathrm{EDI} = \frac{\text{Tomato consumption} \times \text{pesticide concentration in the tomato}}{\text{Body Weight}}$$

2.8. Estimation of health risk from pesticides

The risk of exposure to a pesticide by an individual farmer was estimated on the basis of the potential health risk index for noncarcingenic chemicals according to Akoto, Gavor, Appah, and Apau (2015) using the following formula:

$$\mathrm{HRI} = \frac{\mathrm{EDI}}{\mathrm{ADI}}$$

where HRI is stands for health risk index, EDI stands for estimated daily intake, ADI stands for acceptable daily intake. According to Akoto et al. (2015) when HRI is greater than one, lifetime consumption of tomatoes containing the measured level of pesticide could pose health risks .

3. Data analysis

The data were coded in the Statistical Package for Social Science version 21.0 (SPSS 21.0) and excel then imported to, R software and graph pad prism for analysis. Chi-square and Fisher's exact test were used to compare pesticide exposure among the farmers for different pesticide malpractices. The Chi-squire test was also employed in linking dietary pesticide exposure and various factors that can influence pesticide exposures including pesticide withdrawal period, level of education, labelling languages and agriculture trainings. Descriptive statistics were used to interpret social and demographic data. The standard error was kept at 5%.

4. Results and discussion

4.1. Socio-demographic characteristics of participants

Social demographic characteristics for the farmers are given in Table 2. All the farmers were adults with the starting age of 18 years. Ninety-four of farmers were able to read and write and their level of education reflected their ability to use Swahili language. Ninety-six percent of the respondents were smallholder farmers with the 82% owning from 5.1 to 10 acres of land. Four percent were medium scale farmers owned more than 10 acres, farms.

Table 2. Socio-demographic characteristics

Demographic characteristics	Frequency (*n*)	Percent (%)
Gender		
Male	43	86
Female	7	14
Age group		
18–20 years	6	12
21–30 years	14	28
31–40 years	14	28
41–50 years	10	20
51–60 years	1	2
>60 years	5	10
Occupation		
Farmer	48	96
Farmer cum entrepreneur	2	4
Education level		
Incomplete primary	3	6
Primary	33	66
Secondary	13	26
College/ University	1	2
Farm size		
1–5 acres	7	14
5.1–10 acres	41	82
10.1–15 acres	1	2
>15 acres	1	2

4.2. Pesticide used in tomato production

Farmers used different types of pesticides as indicated in Figure 1 where among the fungicides dithiocarbamites and, pyrethroids were the most used among the fungicides and insecticides, respectively. Mdegela et al. (2013) reported as well a high proportion and quantity of pyrethroid for pesticides used at Mindu dam catchment area in Morogoro. All the registered pesticides used by farmers in Tanzania are in class II which are moderately hazardous (TPRI, 2007; WHO, 2010). When carefully handled Class II pesticides are considered to be of low health effects.

4.3. Method quality assurance

Before analysis of a pesticide, recovery experiments were carried out on tomato samples known to be free from pesticide residues. The sample was spiked at five concentration levels of chlorpyrifos, permethrin and ridomil: 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 mg/kg. The spiked samples were extracted and analyzed under the same conditions as stated in subsection 2.4 for the samples. Precision was determined in terms of repeatability, by running three extractions of tomato sample spiked at three different levels (0.5, 1.5, and 3.0 mg/kg). Method linearity was evaluated using linear regression analysis at the spike levels. The limits of detection (LODs) and the limits of quantification (LOQs) of the method were obtained using a signal-to-noise (S/N) ratio of three calculated from the calibration line at the low concentrations (Shrivastava & Gupta, 2011). Three replicates were performed at each spiking level to determine the relative standard deviation (RSD). The percentage recoveries for chlorpyrifos, permethrin and ridomil was calculated using the following formula:

$$\text{Percentage recovery} = \frac{\text{CE}}{\text{CM}} \times 100$$

where CE is the experimental concentration determined from the calibration curve and CM is the spiked concentration (Nur et al., 2015).

Instrumental limit of detection and limit of quantification are as indicated in Table 3.

Figure 1. Percentage of farmers applying different types of pesticides.

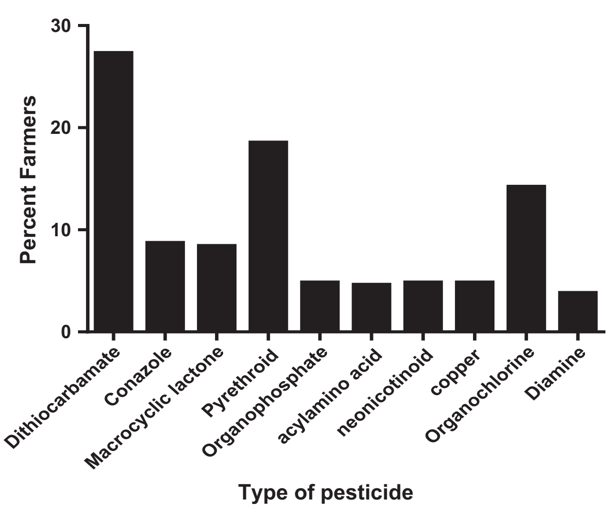

Table 3. Recovery and precision of the GC–MS method for pesticide analysis in fresh tomatoes as determined in triplicate

Pesticide	LOD mg/kg	LOQ mg/kg	Recovery range %	RSDr % (*n* = 3)
Chlorpyrifos	0.246	0.745	77–113	19
Permethrin	0.0074	0.225	72–116	7
Ridomil	0.159	0.482	113	8

The percentage recoveries for all samples ranged from 72% to 116% and the RSD for chlorpyrifos, permethrin and ridomil were 19%, 7%, and 8%, respectively. The percentage recoveries, between 70% to 120% and RSDs ≤ 20% meet the requirement of SANCO guidelines (SANCO, 2013). The limit of detection and limit of quantification for chlorpyrifos, permethrin and ridomil were below the recommended maximum residue limits (MRL) for tomato which show the efficiency of detecting the amount of pesticides which might cause health risks.

4.4. Occurrence of pesticide residues in fresh tomatoes

Table 4 shows the presence of chlorpyrifos, permethrin and ridomil in fresh tomatoes. Chlorpyrifos and permethrin in tomatoes have been detected in different places around the world including India and Ghana (Essumang, Dodoo, Adokoh, & Fumador, 2008; Singh, 2012). The maximum residual levels of 2,854.729 mg/kg, 603.609 mg/kg and 29.055 mg/kg for ridomil, chlorpyrifos and permethrin respectively estimated in this study are higher than the levels previously reported for the respective pesticides, in Ghana by Essumang et al. (2008). In Ghana the levels of 10.76 mg/kg for chlorpyrifos and 0.032 mg/kg for permethrin were reported (Bempah, Asomaning, & Boateng, 2012; Essumang et al., 2008). The high concentration quantified in this study might be attributed to poor pesticide application among the Tanzanian farmers which suggests the increased risk of pesticide exposure for Tanzania consumers. The mean concentration of 7.528 mg/kg for chlorpyrifos, 5.289 mg/kg for permethrin and 2,854.729 mg/kg for ridomil were above their respective MRL which again indicates the unacceptable risks of pesticides exposures in tomato consumers in Tanzania (http://www.fao.org/fao-who-codexalimentarius/standards/pesticide-mrls/en/).

Among the contaminated samples chlorpyrifos and permethrin pesticides were more frequently detected (46.15%) followed by ridomil 7.7%. This might be caused by pesticide misuses such as spraying too close to harvest, over-applying as well as using mixture of pesticide as described by Northern Presbyterian Agricultural Services And Partners (NPAS, 2012).

Chlorpyrifos was among the pesticide used for the highest frequency (31–45%) in vegetable production as compared to other pesticides in Djutitsa Cameroon (Manfo et al., 2012). Chlorpyrifos and permethrin have been also detected in varying concentration in other food products in Africa; such as wheat in South Africa, maize and red paper in Ethiopia, watermelon, pear, pineapple and cabbage in Ghana (Bempah et al., 2012; Benson & Olufunke, 2011; Dalvie & London, 2009). According to PSEP

Table 4. Levels of pesticide residues in tomato

	Fresh tomatoes (*n* = 50)	Codex MRL (mg/kg)
Chlorpyrifos		
Positive samples (%)	12	1.0
Geometric mean (mg/kg)	7.528	
Range (mg/kg)	0.833–603.609	
Samples above codex MRL (%)	12	
Permethrin		
Positive samples (%)	12	1.0
Geometric mean (mg/kg)	5.289	
Range (mg/kg)	0.693–29.055	
Samples above codex MRL (%)	12	
Ridomil		
Positive samples (%)	2	0.5
Geometric mean (mg/kg)	2,854.729	
Range (mg/kg)	2,854.729	
Samples above codex MRL (%)	2	

Note: MRL, maximum residue limit.

(2012), Toynton, Luukinen, Buhl, and Stone (2009) and Christensen, Harper, Luukinen, Buhl, and Stone (2009), these pesticides are widely used because they are effective in controlling a variety of insects in crops . This implies that there is a need of regular monitoring for these pesticides in foods to prevent health risks associated with their exposure.

4.5. Multiple pesticide residue levels

Conventionally grown foods often contain residues of more than one pesticides (Baker, Benbrook, III, & Benbrook, 2002). In this study ridomil, chlorpyrifos and permethrin were simultaneously detected in two samples. Tomatoes are sensitive to pests hence require multiple use of pesticides which can be found as residues if not properly used. In Kazakhstan, Lozowicka et al. (2015) detected up to nine pesticide residues including azoxystrobin, metalaxyl, flusilazole and triadimefon. Multiple contamination increases health risks as there could be a possibility of synergism in their effects.

4.6. Tomato consumption patterns

The average per capita intake of fresh tomatoes among the 50 interviewed farmers was 258 g per day which is the approximation of two medium sized tomatoes per day. Per capita consumption of tomatoes ranged from 125 to 562.5 g/day (mean, 202.5 ± 128.5 g/day) which is higher compared to what was reported by Codex Alimentarius Commission (http://www.fao.org/fao-who-codexalimentarius/standards/pesticide-mrls/en/). Higher per capita consumption of tomato obtained from this study reflect increased risk of pesticide exposure to consumers.

5. Risk of exposure

Adult individuals were involved in the pesticide dietary exposure assessment of tomatoes. ADI, EDI, HRI and percent of individuals with HRI above one are as presented in Table 5. HRI for chlorpyrifos, permethrin and ridomil are greater than one indicating lifetime consumption of fresh tomatoes with the measured pesticide residue pose health risk. The findings from this study show that, five farmers are susceptible to health risks associated with pesticide exposure since their HRIs are above one. This result is higher than what was previous reported by Akoto et al. (2015) where HRI of tomatoes from Kumasi, Ghana for chlorpyrifos and permethrin were 0.0041 and 0.0002 respectively presenting no health risks to consumers. Despite the risks of ridomil pesticides to consumers no report provided the HRI for ridomil exposure of fresh tomato. It should be noted that, the exposure estimated in this study did not include other types of pesticide exposures or other types of foods consumed by the farmers hence the total exposure of pesticides among these farmers might be higher than it has been reported.

ADI according to Codex Alimentarius Commission (2013).

Table 5. Mean concentration, ADI, EDI, and health risk estimation for pesticide residues detected in tomato samples

Pesticide	Geometric mean (mg/kg)	ADI[a] (mg/kg)	EDI[b] (mg/kg)	HRI[c]	Percent individuals with HRI above one
Chlorpyrifos	7.5281	0.01	0.0293	2.9293	6
Permethrin	5.2899	0.08	0.0206	0.4117	4
Ridomil	2,854.7291	0.05	11.1081	138.851	2

[a]Acceptable Daily Intake.
[b]Estimated Daily Intake.
[c]Health Risk Index.

Table 6. Odds ratio for the likelihood of association between exposures to pesticide in freshly harvested tomatoes and different factors

Factor	*p*-value	Odd ratio	95% confidence interval
Selling before pesticide withdrawal period	0.0041*	26	2.469–273.8
Primary school education	0.00064*	39	3.754–405.2
English as a labelling language	0.04*	8.143	1.144–57.98
Improper disposal of pesticide containers	0.04*	8.2	1.144–581
Lack of training on agriculture science	0.0001	101.4	4.781–2152
Use of Pesticide Mixtures	0.044*	7.800	1.224–49.70
Repeated pesticide application	0.029*	54.09	2.451–1194
Overdosing pesticides	0.063	13.67	1.068–174.9

*p-value < 0.05 indicate significance association.

5.1. Factors associated with risk of pesticide exposures

5.1.1. Pesticide overdose

Eighteen percent of farmers overdosed pesticide in tomato treatment. This is partly due to the presence of resistant pests and diseases. The use of pesticide in higher dosage than recommended might be the cause for pest resistant and high accumulation of residues in tomatoes which increase to risk of exposure. Ngowi et al. (2007) reported that, farmers use pesticide depending on the pest population and their potential damages as well as their perception on pests a management practices. Despite the risks associated with pesticide overdose, this study could not find significance relationship with pesticide dietary exposures ($p = 0.063$).

5.1.2. The use of pesticide mixtures

Thirty-eight percent of farmers use pesticide in mixed formulations whereby they mix several pesticides in a single tank and apply to their farms. Pesticide mixing increases the risk of exposure and pest resistance (Ngowi et al., 2007). There is significance association between using mixtures of pesticides and pesticide exposures ($p = 0.044$). As it has been indicated in Table 6, the odds ratio for pesticide dietary exposure was seven times higher for the farmers who use pesticides in the mixtures than others. The use of pesticide in a mixture was also found among the vegetable farming in Ghana as well as in the Northern zone of Tanzania as a means of labour and cost serving (Ngowi et al., 2007; NPAS, 2012).

5.1.3. Repeated pesticide application

Repeated pesticide application is linked to over applying of pesticide regardless of the safety implications. In this study 20% of farmers repeat the use of pesticides when there is persistent pests in their crop. As shown in Table 6, the odds ratio for being exposed to pesticide in fresh tomatoes was 54 times higher for the farmers who repeated pesticide application than others ($p = 0.029$). This findings show that, repeated pesticide application in tomatoes is more likely to cause pesticide residues and exposures compared to other pesticide malpractices. The higher frequency of pesticides application is a result of preventive measure for pest problems as compared to curative application after pest observation (Ngowi et al., 2007). The current increase in pesticide use is attributed to the occurrence of new pests and diseases specifically *Tuta absoluta*. This is a type of tomato leaf miner which is a devastating pest of tomato originating from South America causing as high losses as 80–100% (Desneux et al., 2010; Mwatawala, 2013). The pest hinders photosynthesis, which is very crucial for plant growth and attack tomatoes at every stage of its growth. The occurrence of *T. absoluta* in the previous season cause farmers to use more, and mixture of pesticide than it was before. The pest was first identified in Tanzania on August 5 2013, in Ngabobo village, Ngarenanyuki (one of the wards studied in this study), King'ori in Meru district. The pest was also reported in other countries such as Kenya, Ethiopia and Eritrea in 2013 (Mwatawala, 2013). Multiple use of pesticides can be the cause of multiple pesticide residues and exposure. Extension services should be readily available during the outbreak of new pests and diseases.

5.1.4. Selling tomatoes before pesticide withdrawal period

Twelve percent of farmers confirmed to sell tomatoes without observing pesticide withdrawal period. This study shows a strong association between the risk of pesticide exposure among the farmers who sell tomatoes without considering safe period after pesticide application ($p = 0.041$). The odds ratio of exposure for those who sell before pesticide withdraw period is 26 times higher than those who observe the withdrawal period. Farmers who sell tomatoes without considering safe time of consuming them after pesticide application are more likely to consume the same tomatoes and consequently expose themselves to pesticide risks. Busindi (2012) reported on the tendency of tomato farmers to apply pesticides one day instead of seven days before harvesting as well as one week after harvesting to increase tomato shining. Limited observation of pesticide withdrawal period causes residues in food and influence pesticide dietary exposure (Ayres, Harrison, & Nichols, 2010). Training on safety handling of pesticides among tomato farmers should be considered to protect consumers on pesticide exposure.

5.1.5. Pesticide labelling and level of education

There is a significant relationship between pesticide exposure and the use of English labelled pesticides ($p = 0.04$). The instructions in the labels are very important for protecting pesticide handlers and consumers against exposure (Lekei, Mununa, & Uronu, 2004). The odds ratio for exposure of pesticide is eight times higher for English labelled pesticides compared to pesticides with Swahili labels. Despite the farmers reported on the use of registered pesticides, presence of only English labelled pesticides in the market, indicates that, farmers are using unregistered pesticides as the legal language for pesticide labelling in Tanzania is both English and Swahili. Language barrier in pesticide label was also reported in previous studies at Manyara basin and Mindu dam catchment area (MDCA), in Morogoro (Mdegela et al., 2013; Nonga, Mdegela, Lie, Sandvik, & Skaare, 2011). Perhaps the problem of language is linked to the level of education because a strong association between pesticide exposure and primary education (0.00064) was also identified in this study (Table 6). The odds ratio for being exposed to pesticide for famers having primary school level of education is 39 times higher than for the other age groups. There is a need for regular monitoring of pesticides used by farmers to ensure labelling languages meet the registered standards.

5.1.6. Improper pesticide disposal practices

Twelve percent of farmers disposed empty pesticide containers with other wastes or within the fields. This practice was also reported by Lekei, Ngowi, and London (2014) and Khan, Shabbir, Majid, Naqvi, and Khan (2010) in Arumeru and Pakistan respectively. The practice can cause accumulation of pesticide in soil and water sources as it was detected in a sample of irrigation water in Ngarenanyuki ward in Meru district (Kihampa et al., 2010b). Some pesticides' active ingredients might not be able to decompose in the soils or water hence can be the cause for pesticide residues in tomatoes. A strong association was observed between pesticide residues and exposure above ADI and percent of farmers who dispose their pesticide containers with other waste ($p = 0.04$). The odds ratio for exposure of pesticide is eight times higher for farmers who dispose pesticide containers with other wastes and in their farms than other those who disposed them otherwise.

5.1.7. Agriculture trainings and knowledge associated with unacceptable exposures

Agriculture trainings are long term solution for pesticide problems in developing countries and useful to monitor pesticide use among farmers (Ecobichon, 2001). The odds ratio analysis has shown that, those who had not received any agriculture trainings have 101.4 times higher risk of being exposed above ADI than those who had been trained. The problem of low awareness on pesticides effects is not unique to Tanzania. It was observed in Washington state that, pesticide exposure among the farm workers is less understood (Coronado, Thompson, Strong, Griffith, & Islas, 2004). Most farmers are aware of acute pesticide toxic effects, but they remain unaware of long term effects of pesticides (Atreya, 2007; Bhanti, Shukla, & Taneja, 2004; WHO, 2009). Lack of awareness on

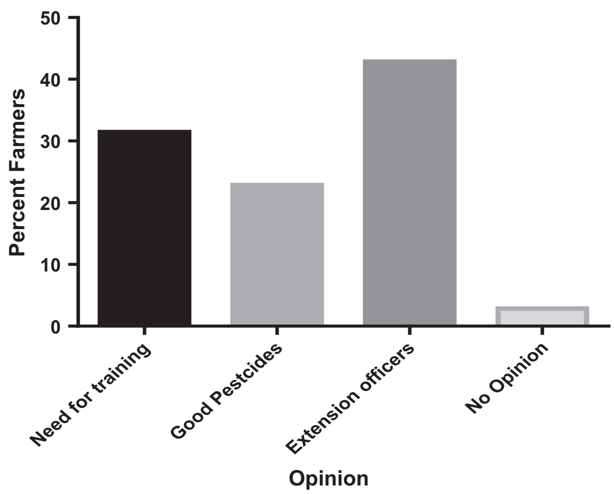

Figure 2. Percent of farmers with different opinions on how to improve pesticide application practices.

long term effects of pesticides is due to the association of other medical illnesses related to pesticide exposure. In this study only two percent of farmers are aware of pesticide effects to consumers which can threaten consumers' health. Hence there is a need of raising farmers awareness on the possible risk of exposures due consumption of pesticide contaminated tomatoes. Not only that but also regular trainings on pesticide use among tomato farmers are very crucial to minimize pesticide risks to consumers.

5.2. Farmers' opinions on how to improve pesticide application practices

Farmers recommend provision of agriculture trainings, extension services and good pesticides as indicated in Figure 2. Agriculture training and access to extension services may enable the farmers to acquire knowledge on the right use of agricultural inputs (Daniel et al., 2013). On good pesticide recommendation, the farmers refer to a single pesticide formulation which cures all the pests. This view is also supported by Bhanti et al. (2004) in the study done in rural India. This may be due to the cost in terms of finance and time of spraying as well as the desire to be assured for prevention of all pests at a particular time.

6. Conclusion and recommendations

Adults consuming various forms of fresh tomatoes in Tanzania are at a risk of being exposed to chlorpyrifos, permethrin and ridomil pesticides. The findings from this study have indicated poor pesticide handling practices, especially when there is an eruption of new pests and diseases. Repeated pesticide application and using mixtures of pesticides are highly linked with risk of exposure of pesticide in fresh tomatoes. Raising of public awareness on good practices for pesticide application and strengthening of foods safety control services for pesticide control as measures to prevent and protect public health against pesticides is recommended. This idea is also supported by Ahmed et al. (2014) in the study of dietary intake based on vegetable consumption in Ismailia, Ghana. Not only that, consumers should diversify the consumption of vegetables as well as consume organically produced tomatoes to meet their nutrition demands and minimize risk of pesticide dietary exposures.

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Competing interests
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